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Previous work at the Lebanon Pilot Plant Facility of the EPA has shown that single stage lime clarification at pH 9.5 will remove 90% or more of the phosphorus present in either primary or secondary effluent but only 70% of the phosphorus present in raw wastewater (1) (2) (3). Subsequent bench studies indicated that to achieve 90% phosphorus removal from raw wastewater it is necessary to lime to a pH of 11. This report presents the results of the pilot study that followed in which raw wastewater was lime clarified at pH 11 and then granular carbon treated.

Other than to look at the phosphorus removal performance of a single stage lime clarifier operating at a high pH, other purposes in conducting the study were to gain some insight into the economics of liming to pH 11, and the operational problems associated with liming to pH 11.

PILOT SYSTEM

Figure (1) gives a flow diagram for the pilot physical and chemical treatment system studied. Raw wastewater, sized and degritted, from the Lebanon, Ohio municipal treatment plant, was fed first to an upflow lime clarifier for removal of suspended organic and inorganic matter, and phosphorus. After liming to pH 11 the lime clarified water was filtered through two dual-media filters to capture any suspended matter escaping the clarifier. Following filtration, the filtered water was pumped first to a holding tank and then from the holding tank through carbon contactors for removal of soluble organic matter.

The activated carbon adsorption process consisted of two carbon contactors, each containing 1500 pounds of 8 x 30 mesh granular activated

carbon. This quantity of carbon filled a contactor to a depth of five feet. The contactors were operated upflow and in series. The second contactor was oxygenated at the rate of 10 CFH to prevent anerobiosis of the contactor.

Prior to dual-media filtration, the clarifier effluent was adjusted to pH 8 with sulfuric acid to minimize calcium incrustation of the filter media. Following filtration, the clarified effluent was further adjusted to pH 7.5 with sulfuric acid prior to carbon treatment.

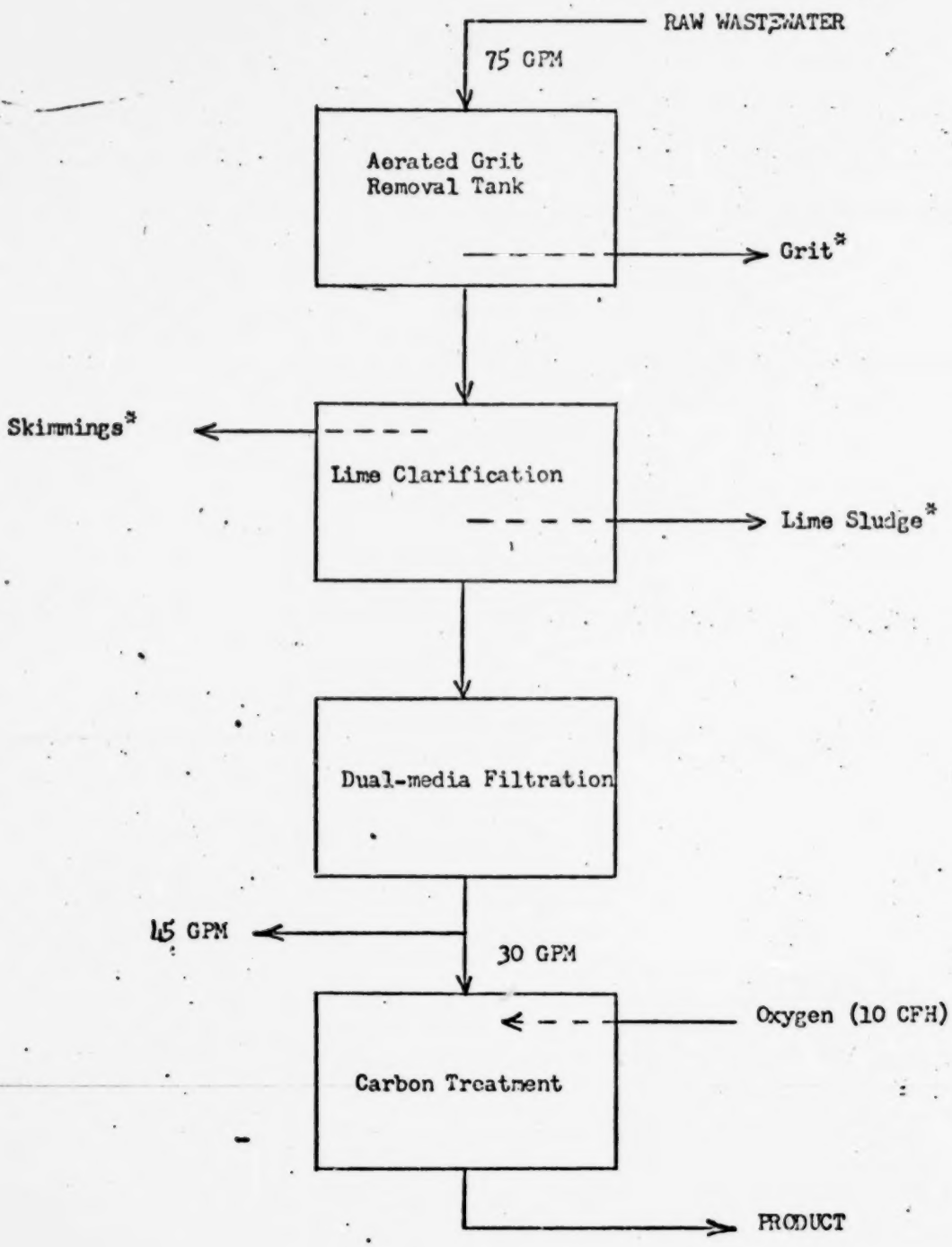
The lime clarification process was operated at a constant flow rate of 75 gal/min. Part of this flow was stored for use in the backwash of the dual-media filters; the remainder of the flow went to the holding tank ahead of the carbon contactors. At a flow of 75 gpm, the rise rate of the lime clarifier was 1 gpm/ft^2, and the surface loading of the dual-media filters was 2 gpm/ft^2 each.

Lime clarified and filtered water was pumped from the holding tank through the carbon contactors at a constant rate of 30 gal/min. At this flow rate the surface loading of the carbon contactors was 2.4 gpm/ft^2, and the empty bed residence time was 15.7 minutes for each contactor or a total of 31.4 minutes for the carbon treatment process as a whole.

Operation of the treatment system was continuous over a 24-hour period. The lime clarification process never required shutdown during the runs. Since the carbon contactors were operated upflow and slightly fluidized, they did not require shutdown for backwashing.

Samples of the feed and product streams of the lime clarification process were taken for analysis of TOC, turbidity, suspended solids, and

FIGURE 1. Flow Schematic of the pilot system.



* Disposed of to sand drying beds.

phosphorus. The feed and product streams of the carbon process were sampled for TOC, and turbidity measurements.

All samples were analyzed by Standard Methods except turbidity and TOC (7). Turbidity results were obtained using a Hach turbidimeter.* Two TOC analyses were made with a Beckman Carbonaceous Analyzer.+

RESULTS & DISCUSSION

Nutrient Removal. Averaged over a twenty day operational period, lime clarification removed 90% of the total phosphorus and 92% of the ortho phosphorus (Table 1). Dual-media filtration removed a small additional amount of phosphorus. No perceptible removal of phosphorus occurred in the carbon contactors.

Nitrogen was not monitored about the treatment system. Previous experience has shown that only minor removal of nitrogen occurs upon lime clarification and filtration principally through the removal of suspended organic nitrogenous matter (1) (4). Other minor nitrogen removal possible occurred through stripping effects of the oxygenation of the carbon contactors and through diffusion of ammonia from the water into the atmosphere (4).

Organic Removal. The physical-chemical system achieved a high level of organic matter removal (Table 1). Lime clarfication removed 65% of the total organic carbon (TOC), and filtration an additional 8%. Carbon treatment removed 21% of the TOC. Overall the system removed 62 mg/l or 94% of the TOC. Of the 62 mg/l TOC removed, 48 mg/l or 77% was substantially suspended and 14 mg/l or 23% principally soluble in form.

* Model 1760 Laboratory Turbidimeter, Hach Chemical Company, Ames, Iowa
\+ Beckman Instruments, Inc., Fullerton, California

TABLE 1

Contaminant Removal by Clarification, Dual-media Filtration, and Carbon Treatment

	Influent, mg/l	Clarification		Filtration		Carbon Treatment	
		Residual mg/l	% Removed*	Residual mg/l	% Removed*	Residual mg/l	% Removed*
Organic Matter (as TOC)	66	23	65	18	73	4	94
Phosphorus							
Total	7.4	0.7	90	0.6	92	-	92
Ortho	6.8	0.5	92	0.6	91	-	91
Suspended Solids	166	65	60	5	97	4	98
Turbidity **	56	20	64	4	93	6	89
Magnesium	30	11	63	11	63	-	63

* Accumulative percent removal

** Turbidity in Jackson Turbidity Units

Other Contaminant Removal. Lime clarification and dual-media filtration removed 97% of the suspended matter and an addition 1% was removed in the carbon system (Table 1). Clarification and filtration removed 93% of the turbidity matter but carbon treatment decreased the overall removal of turbidity to 89%. The increase in turbidity is attributed to the sloughing of biological matter from the carbon contactors. Although not considered a contaminant, 63% of the magnesium present was removed during clarification.

System Performance at pH 9.5 and pH 11. Table 2 summarizes the performance of the pilot system when operated at pHs 9.5 and 11. The pH 9.5 data is from Villiers (3).

The only significant difference in product parameters is the 16 % increase in phosphorus removal. The increase in TOC removal and the resultant low TOC residual obtained at pH 11 is due to the light organic loading of the carbon.

Lime Requirements. On the average, 700 mg/l of slaked lime were required to raise the pH of the raw wastewater to pH 11. About 200 mg/l of lime are required to raise the pH of raw wastewater to pH9.5 (3). Also, 200 mg/l of lime are required to raise the pH of primary or secondary effluent to pH 9.5 (2) (5). Thus, around 500 mg/l more lime is required to remove 90% of the phosphorus in raw wastewater than is required to remove the same amount from primary or secondary effluent.

CONCLUSIONS

The precipitation of magnesium hydroxide at pH 11 is the probable controlling factor in achieving high phosphorus removal from raw wastewater in a single stage lime system. The additional 16% phosphorus removed at pH 11 vs. pH 9.5 (Table 2) is probably polyphosphates, possibly

TABLE 2

COMPARATIVE PERFORMANCE RESULTS OF THE TREATMENT SYSTEM AT pH 9.5 AND pH 11

	Influent mg/l	Clarification and Filtration Residual mg/l	Clarification and Filtration % Removed*	Carbon Treatment Residual mg/l	Carbon Treatment % Removed*
pH9.5					
Organic Matter (as TOC)	87	24	72	9	90
Phosphorus (Total)	7.8	1.9	76	-	-
Suspended Solids	110	7	94	2	98
Turbidity**	54	5	91	4	93
pH11					
Organic Matter (as TOC)	66	18	73	4	94
Phosphorus (Total)	7.4	0.6	92	-	-
Suspended Solids	166	5	97	4	98
Turbidity*	56	4	93	6	89

* Accumulated percent removal
** Turbidity in Jackson Turbidity Units

colloidal, that are coprecipitated with the magnesium hydroxide. The following general reactions are suggested:

(1) $P_o + P_p \xrightarrow{\text{(Hydrolysis)}} P_s \longrightarrow C_a P_s$ Primary effluent pH 9.5, 90% Removal

(2) $P_o + P_p \xrightarrow{\text{(partial) (hydrolysis)}} P_s + P_p \longrightarrow P_p + C_a P_s$ raw wastewater pH 9.5, 75% Removal

(3) $P_o + P_p \longrightarrow P_s + P_p \longrightarrow C_a P_s + P_p$ raw wastewater pH 11. 90% P removal

$P_p + Mg(OH)_2 \longrightarrow Mg(OH)_2 P_p$

P_o = orthophosphate

P_p = polyphosphate

Other than to increase phosphorus removal from 75% to slighter greater than 90%, liming raw wastewater to pH 11 versus pH 9.5 accrued no significant benefit. To achieve the 16% increase in phosphorus removal an additional 4200 lbs. of lime is required per million gallons of raw wastewater. This amounts to a chemical cost increase of 4.2 ¢/1000 gallons or about 1¢/1000 gallons for each additional mg of phosphorus removed (75% versus 90% of 7.4 mg/l phosphorus, see Table 2). However, if the spent lime were re-calcined and recycled optimistically 75% of this cost could be recovered leaving a final cost of about 1¢/1000 gallons.

Capital costs including initial lime requirements could be influenced greatly by increasing lime dosages. On a million gallon basis, liming to pH 9.5 produces about 2300 lbs. of lime sludge whereas liming to pH 11 about 7900 lbs. are produced. The difference, some 5600 lbs. of sludge would increase the sizing of hardware associated with sludge handling, processing, and ultimate disposal.

For 90% phosphorus removal, the total costs of liming raw wastewater to pH 11 need be compared to the total costs of primary treatment followed by liming to pH 9.5. The key cost in the latter route is the cost of handing, processing and ultimately disposing of the primary sludge solids. Possibly these solids could be blended with the lime sludge, then dewatered along with the lime sludge and ultimately disposed of by incineration during recalcination of the lime. The addition of lime sludge to primary sludge would have the added benefit of increasing the dewatering characteristics of the primary sludge.

COSTS

The chemical costs to lime raw wastewater to pH 11 are estimated at 4 ¢/1000 gallons. Recalination and recycle of the lime could lower these costs slightly. Dual-media filtration would add about 1-2 ¢/1000 gallons. Cost for carbon treatment including carbon regeneration and recycle are estimated at 7-8 ¢/1000 gallons.

The above costs are based on a 100 mgd plant. At smaller plant sizes the costs could be significantly greater.

SUMMARY

Liming raw wastewater to pH 11 removes 90% or more of the phosphorus. Lime requirements to achieve pH 11 averaged 700 mg/l as slaked lime. Other than increased phosphorus removal 90% versus 75%, liming to pH 11 as compared to liming to pH 9.5 (200 mg/l) had no significant influence on product quality. No significant improvement in TOC removal was obtained by carbon treatment following liming at pH 11 versus pH 9.5, The total cost to lime clarify at pH11, dual-media filter and then carbon treat is estimated at 0.12-0.14/1000 gallons at a plant size of 100 mgd.

REFERENCES

1. Villiers, R. V., Berg, E. L., Brunner, C. A., and Masse, A. N., "Treatment of Primary Effluent by Lime Clarification and Granular Carbon," Preprint 14, 1, American Chemical Society, Joint CIC-ACS Conference, Toronto, Canada, May 1970.

2. Villiers, R. V., Berg, E. L., Brunner, C. A., and Masse, A. N., "Municipal Wastewater Treatment by Physical and Chemical Methods," Water and Sewage Works, 1971 Reference Edition.

3. Villiers, R. V., "Municipal Wastewater Treatment by Single Stage Lime Clarification and Activated Carbon". (Submitted for Publication).

4. Bishop, D. F., O'Farrell, T. P., and Stamberg, J. B., "Physical-Chemical Treatment of Municipal Wastewater."

5. Berg, E. L., et al., "Single Stage Lime Clarification of Secondary Effluent," Water and Wastes Engineering (March, 1970).